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WCRP SURFACE RADIATION BUDGET SHORTWAVE DATA PRODUCT DESCRIPTION - VERSION 1.1

C. H. Whitlock, T. P. Charlock, W. F. Staylor, R. T. Pinker, I. Laszlo, R. C. DiPasquale and N. A. Ritchey

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(VERSION 1.1)

by

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ABSTRACT

Shortwave radiative fluxes which reach the Earth's surface are key elements that influence both atmospheric and oceanic circulation. The World Climate Research Program has established the Surface Radiation Budget climatology project with the ultimate goal of determining the various components of the surface radiation budget from satellite data on a global scale. This report describes the first global product that is being produced and archived as part of that effort. The interested user can obtain the monthly global data sets free of charge using email procedures.

1 INTRODUCTION

Radiation fluxes reaching the Earth's surface are principal elements in the total energy exchange between the atmosphere and the land or ocean surfaces. Surface radiation exchanges influence both atmospheric and oceanic circulations. A Surface Radiation Budget (SRB) climatology project was established under the World Climate Research Program (WCRP) following recommendations from the international science community (Suttles and Ohring, 1986). The goal was the determination of the various components of SRB globally from satellite observations.

Since 1986, the WCRP/SRB project has tested a number of shortwave (SW) and longwave (LW) satellite algorithms with special field experiments and experimental global processing studies. This testing has been coordinated with two international science groups--the SRB Science Working Group (SRB/SWG) and the WCRP Working Group on Radiation Fluxes (WCRP/WGRF). A number of SW algorithms have been shown to be accurate within 10 W/m**2 under ideal conditions when satellites are accurately calibrated and no data gaps exist (Whitlock et al., 1990a). Experimental global processing studies using data from the International Satellite Cloud Climatology Project (ISCCP) have shown that two SW algorithms have sufficiently accurate data gap filling procedures to warrant the production of long-term global data sets (World Climate Research Program, 1992, p. 6). The first WCRP/SRB SW global data set (Version 1.1) is a quick-look, interim product for the period between March 1985 and November 1988. This is a period where the ISCCP data used as input are considered most accurate.

It is the purpose of this document to provide an in-depth technical description of the Version 1.1 WCRP/SRB SW global data set for potential users. The information included is similar to that in a README file (named srb_readme_yymm) with each month's data package. It should be emphasized that the srb_readme_yymm file may be quite different from month to month, depending on satellite calibration and ground-truth comparison results. This document uses the July 1985 data month as an example to describe the SRB product.

The SRB Satellite Data Analysis Center (SDAC) is indebted to Dr. Robert Schiffer (WCRP Radiation Projects Office, NASA Headquarters, U.S.A.) and Dr. James Dodge (NASA Headquarters, U.S.A.) for their guidance and support during development and implementation of this activity.

Input from the SRB/SWG was invaluable in defining which parameters to include in the SRB data set as well as analysis of the experimental global processing results. That group is chaired by Dr. T. Charlock (NASA Langley Research Center, U.S.A.), and membership includes Drs. A. Arking (NASA Goddard Space Flight Center, U.S.A.), R. Ellingson (University of Maryland, U.S.A.), C. Frohlich (World Radiation Center, Physikalisch-Meteorologisches Observatorium, Switzerland), W. Liu (NASA Jet Propulsion Laboratory, U.S.A.), G. Ohring (NOAA National Environmental Satellite Data Information Service, U.S.A.), J. Schmetz (European Space Operations Center, Germany), and G. Stephens (Colorado State University, U.S.A.).

We are also indebted to the WCRP/WGRF for their review and advice during the SRB development process over the past 6 years. That group is chaired by Dr. T. Vonder Haar (Colorado State University, U.S.A.) and membership includes Drs. A. Arkin (NASA Goddard Space Flight Center, U.S.A.), Y. Fouquart (Universite des Sciences et Techniques de Lille, France), V. Khvorostyanov (Central Aerological Observatory, Russian Federation), J.-J. Morcrette (European Center for Medium-Range Weather Forecasts, United Kingdom), T. Nakajima (University of Tokyo, Japan), G. Ohring (NOAA National Environmental Satellite Data Information Service, U.S.A.), E. Raschke (GKSS-Forschungzentrum, Germany), R. Saunders (Royal Aerospace Establishment, United Kingdom), A. Slingo (Meteorological Office, United Kingdom), and G. Stephens (Colorado State University, U.S.A.).

2 CONCEPTUAL FRAMEWORK FOR INTERIM SRB PROCESSING

Using ISCCP 3-hourly parameters as primary input (Rossow et al., 1991), SRB results are generated using two different algorithms. The two methods use different approaches. Both methods apply spectral and angular corrections (based on Nimbus-7 Earth Radiation Budget (ERB) and Earth Radiation Budget Experiment (ERBE) results) which are not included in the original ISCCP data. They also separate surface from aerosol effects, which is not included in ISCCP. Each method uses its own cloud algorithm which has been compared with experimental data from a number of regions. SDAC also compares basic SRB results with a limited amount of ground truth data that are available. The user may have increased confidence in the SRB results for those cells wherein the two methods obtain values that differ only slightly. Caution is suggested for those cells where the two methods differ by a large amount.

One algorithm was developed jointly by Drs. R. T. Pinker and I. Laszlo from the University of Maryland (hereafter referred to as the Pinker algorithm). The Pinker algorithm is a physical model which uses an iterative procedure based on delta-Eddington radiative transfer calculations. The other algorithm was developed by Mr. W. F. Staylor from the NASA Langley Research Center (the Staylor algorithm). The Staylor algorithm is a parameterized physical model which uses ISCCP radiances, Tiros Operational Vertical Sounder (TOVS) meteorology, and climatological aerosols to determine the clear atmospheric and cloud transmission characteristics. Both methods have been demonstrated to satisfy the Intercomparison of Radiation Codes in Climate Models (ICRCCM) model-validation tests using standard atmospheric profiles. For this SRB application, they use ISCCP scaled-radiance, cloud amount, precipitable water, and ozone parameters for input. The Pinker algorithm assumes accurate satellite calibration by ISCCP. The Staylor algorithm uses a relative threshold technique and is less sensitive to satellite calibration errors. Details about both methods are given in Appendices A and B.

The month is defined in terms of Greenwich time and dates. Thus, the local-time beginning and ending of the month will vary with cell location.

SRB uses the same grid system as that used by ISCCP for its C1 products. The system is an equal-area grid with a cell size of approximately 280x280 km (Rossow et al., 1991).

Monthly averaged radiative fluxes are based on an average of 24-hour daily values. Certain other items (defined in section 7) are simple linear averages of values during daylight hours.

3 ORGANIZATION OF THE SRB DATA PRODUCT

The data product for each month consists of six files. The following paragraphs give a general description of each file.

The first file is the ASCII-format header file named srb_readme_yymm (srb_readme_8507, for example). This README file contains a wide range of information about the data set as well as specific information about the particular month for which data were processed. The following subjects are included:

I. GENERAL INFORMATION
II. CONCEPTUAL FRAMEWORK FOR SRB PROCESSING
III. SATELLITE CALIBRATION VALUES USED TO DERIVE SRB RESULTS
IV. COMPARISON OF SATELLITE-INFERRED SRB RESULTS WITH GROUND TRUTH
V. DEFINITIONS OF SRB PARAMETERS AND CODES
   A. DEFINITION OF 52 ITEMS IN MONTHLY BINARY FILE srb_monavgs_yymm (srb_monavgs_8507, for example)
   B. DEFINITION OF 10 ITEMS IN DAILY BINARY FILE srb_dayavgs_yymm (srb_dayavgs_8507, for example)
   C. DESCRIPTION OF BINARY HIERARCHICAL DATA FORMAT (HDF) FILES
VI. DESCRIPTION OF PINKER METHOD
VII. DESCRIPTION OF STAYLOR METHOD

The second and third files are in ASCII format showing Fortran listings of the Pinker and Staylor algorithms (srb_pinker.for and srb_staylor.for, respectively). These files are intended to show the programming logic, procedures, and numerical assumptions which may influence results. They do not contain extraneous input files and cannot be compiled as Fortran code.

The fourth and fifth files are binary data files in HDF format, Version 3.2r1. The fourth file (srb_monavgs_yymm) contains monthly average values for 52 different items from several different sources. In addition to SRB values, supplementary data are provided in order to understand causes and effects of variations in the SRB product. The fifth file (srb_dayavgs_yymm) contains 24-hour daily average values for 10 key SRB items.

The sixth file (srb_mon_img_yymm.hdf) is a graphics file which contains 19 global images in HDF format. The intent is to allow the user to quickly browse the most important SRB parameters without the requirement to read the entire data set.

The first, fourth, fifth, and sixth files change each month.

When SRB data are distributed on a CD-ROM, file names are changed in order to accommodate IBM personal computer DOS format as follows:

ARCHIVE FILE NAME	CD-ROM FILE NAME
******************	*****************
srb_readme_yymm	srb_yymm.doc
srb_pinker.for	pinker.for
srb_staylor.for	staylor.for
srb_monavgs_yymm	mon_yymm.hdf
srb_dayavgs_yymm	day_yymm.hdf
srb_mon_img_yymm.hdf	img_yymm.hdf

When distribution is by email, the user may rename the archive file names to his or her system requirements as he gets the individual files from the archive.

The convention used for version numbers of the SRB data set is as follows:

1. A change in the output products will constitute a change in the integer part of the version number. For example, increasing the number of parameters in the monthly file from 52 to 55 would cause a change from Version 1.0 to Version 2.0.

2. A change in the method of computing a parameter or a set of parameters will constitute a change in the tenths part of the version number. For example, a change in the Pinker algorithm caused the version number to increase from 1.0 to 1.1.

3. Revisions made because of errors in the input data or data processing procedures will be labled r1, r2, etc. after the version number. For example, reissue of a data month because of an updated ISCCP tape would cause the version to change from 1.1 to 1.1.r1.

All months with the same version number use the same algorithms and are comparable to each other independent of their r number.

The SRB shortwave data product is archived in the Earth Observing System Data Information System (EOSDIS) at the Langley Distributed Active Archive Center (DAAC). The primary means of transfer for the SRB data package will be by electronic TCP/IP and FTP procedures rather than the traditional mailing of data tapes. Software for reading the HDF format files on various computers is available. The above service is expected to be free of charge. Other data transfer media are also available from the archive on request; however, there may be nominal costs. To access the data set, users may contact the Langley DAAC User Services by telephone at (804) 864-8656 or by email at userserv@eosdis.larc.nasa.gov.

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4 GENERAL INFORMATION

A summary statement similar to that below is given in the README file each month. This is to provide the user with data inputs and processing details particular to each data month.

1. DATA DATE = JULY 1985
2. PROCESSING DATE = OCTOBER 15, 1992
3. SRB VERSION NUMBER = 1.1
4. CHANGES SINCE LAST VERSION FOR THIS DATA DATE = Update to Pinker algorithm to improve agreement with top-of-atmosphere ERBE results.
5. ISCCP C1 VERSIONS USED AS INPUT (2 PER MONTH):
   1st Half = Vol. ID Ver. 0
   2nd Half = Vol. ID Ver. 0
6. ERBE SATELLITES USED TO CONSTRUCT ERBE MONTHLY-AVERAGE VALUES = ERBS and NOAA-9.
7. GENERAL COMMENTS: None for this month.

5 SATELLITE CALIBRATION VALUES USED TO DERIVE SRB RESULTS

ISCCP performs an absolute calibration of the polar orbiter instrument with an uncertainty not exceeding 7 percent (Rossow et al., 1991, p. 25). Comparison of ISCCP calibration with other methods suggests that the above statement is valid during the NOAA-9 period (see Whitlock et al., 1990b). ISCCP also normalizes each geostationary satellite visible-wavelength channel to that of the NOAA polar orbiter to be within plus or minus 5 percent relative to each other (Rossow et al., 1991, p. 25). The absolute calibration equations that result from the ISCCP calibration/normalization process are given in Rossow et al., 1992.

SRB results depend on the accuracy of ISCCP reported radiances. The conversion of measured counts to radiance values depends on the accuracy of the satellite calibration equation for the particular instrument in use. Because of its critical importance, ISCCP satellite calibrations are tested each data month using both the Staylor and Pinker algorithms.

Top-of-atmosphere (TOA) thick-cloud albedos can be compared for each satellite using Staylor's overcast reflectances (eqn (B18)) converted to albedo using the satellite coefficients D1 and D2 as described in Appendix B. For a 45 degree solar-zenith angle, cloud albedo = (2.82843*D1) + (0.23725*D2). Typical thick-cloud albedos are as follows:

DATA MONTH = JULY 1985

TOP-OF-ATMOSPHERE THICK-CLOUD ALBEDO FROM THE STAYLOR ALGORITHM
(SOLAR ZENITH ANGLE = 45 DEG)

	NOAA-9	GOES-6	METEOSAT-2	GMS-3
OVERCAST CLOUDS (OPTICAL DEPTH > or = 80)	0.796	0.807	0.806	0.816

Ideally, the above values should be within 5 percent of each other in each data month.

A further test is performed by comparing Pinker algorithm top-of-atmosphere (TOA) SW net flux (derived from ISCCP) with ERBE results over land for the globe between the latitudes of 55 degrees North and 55 degrees South. Ocean cells are not used in the calibration comparison because of different treatments of Sun glint between the ISCCP and ERBE satellite data.

BROADBAND TOA SW NET FLUX DIFFERENCES (PINKER-ERBE)

1. DATA MONTH = JULY 1985

2. BIAS = +3 W/m**2

3. TOTAL RMS = 9 W/m**2

Note: Total RMS error includes bias error.

The absolute uncertainty of the ERBE data is approximately 5-6 W/m**2 (Suttles et al., 1992). Ideally, the bias values should be less than 10 W/m**2 each data month.

It must be emphasized that the above Pinker minus ERBE statistics do not apply for all cells over the globe. Both ERBE all-sky and clear-sky TOA SW net irradiance values are included in the SRB data product as items 21 and 22 in the file srb_monavgs_yymm (see section 7). Cell-by-cell Pinker minus ERBE differences are provided as items 49 and 50 in file srb_monavgs_yymm for those months when ERBE data are available.

6 COMPARISON OF SATELLITE-INFERRED SRB RESULTS WITH GROUND TRUTH

Downward-measured SW fluxes for validation of the satellite-estimated SRB results were provided by Drs. A. Ohmura and H. Gilgen from the Swiss Federal Institute of Technology, Zurich, as part of their monthly average Global Energy Budget Archive (GEBA). Only those sites which are most accurate (GEBA category 88) have been used in this study.

In the comparison of SRB results with ground truth, one should keep in mind that satellite estimates are computed in the intervals between 0.2-4.0 (Pinker) or 0.2-5.0 (Staylor) micrometers while ground truth measurements are for the wavelength interval of approximately 0.3-3.0 micrometers, depending on instrument manufacturer. Therefore, satellite-estimated downward irradiance should be approximately 1-percent higher than ground measurements on a clear day. On an overcast day with a cloud optical depth = 10, the difference is less than 0.02 percent (based on high-resolution spectral calculations supplied by the University of Maryland). Thus, a positive bias between 0 and 1 percent (depending on monthly averaged cloud cover) may be expected when satellite estimates of downward irradiance are compared with ground truth.

Of the ISCCP cells which contain GEBA sites, approximately 75 percent contain only one GEBA site. An intercomparison of satellite results with ground truth values assumes that the fluxes averaged over a month over the entire ISCCP cell are the same as the monthly average of the fluxes over the ground truth site. A site may not be representative of an ISCCP cell if it is in a polluted, obstructed, unusually cloudy, or frequently foggy area relative to the rest of the cell. In some cases (much of Europe and a few other locations), there are multiple ground sites per ISCCP cell. The cell-averaged ground truth values from these few multi-site cells can be used with more confidence.

Comparisons are made for five combinations of ground truth as defined below:

****

1. GERMANY - Three ISCCP cells with seven or more GEBA sites for each cell. There are not enough cells to calculate total RMS statistics. Bias is based on average differences.

****

GEBA SUBSET - GEBA sites in mountains, at high altitudes, or at potentially foggy coastal sites have been eliminated from the TOTAL GEBA SET.

2. EUROPE MULTI-SITE GEBA SUBSET - Multi-site cells in Europe only, most with only two or three sites. (Approximately 20 ISCCP cells.)

3. MULTI-SITE GEBA SUBSET - All multi-site cells from Europe, Canada, the Far East, and Fuji are included. (Approximately 25 ISCCP cells.)

4. GEBA SUBSET multi-site and single-site cells over the globe are included. (Approximately 100 ISCCP cells.)

****

5. TOTAL GEBA SET - All sites pass the GEBA quality test, but many are in mountains, at high altitudes, or at questionable coastal locations. (Approximately 250 ISCCP cells.)

****

Satellite to ground truth comparison results are given for each data month as shown in the following example:

DATA MONTH = JULY 1985

	PINKER BIAS (W/m**2)	PINKER TOTAL RMS (W/m**2)	STAYLOR BIAS (W/m**2)	STAYLOR TOTAL RMS (W/m**2)
1. GERMANY	+3	NA	+2	NA
2. EUROPE MULTI-SITE GEBA SUBSET	+1	18	-2	12
3. MULTI-SITE GEBA SUBSET	+5	21	+1	17
4. GEBA SUBSET	+12	26	+6	26
5. TOTAL GEBA SET	+16	30	+11	28

Note: Total RMS error includes bias error.

Ground-truth values from the GEBA SUBSET are included in the SRB data product as item 25 in file srb_monavgs_yymm (see section 7).

7 DEFINITIONS OF SRB PARAMETERS AND CODES

In an effort to provide additional information that can be used to explain variations in the surface SW irradiance, the SRB data set includes supplemental information from GEBA, ISCCP, and ERBE in addition to SDAC-derived parameters. Of the SDAC-derived parameters, it must be noted that items 23 and 24 in file srb_monavgs_yymm are the only parameters that can be verified with satellite-scale ground truth.

Caution is required in the use of items 30 through 41 because the uncertainty levels of these parameters cannot be determined from satellite-scale ground-truth measurements at the present time. Items 42 through 50 are diagnostic parameters which may aid the user in estimating the uncertainty of non-verified items.

In the definitions which follow, parameter names are noted by all capital letters, and explanations of the parameters are in lower case.

7.1 DEFINITION OF 52 ITEMS IN MONTHLY BINARY FILE srb_monavgs_yymm

Cell information including both ISCCP- AND ERBE-Derived properties:

1. CELL NUMBER (1-6596, beginning at Greenwich South Pole circling East).
2. ISCCP LATITUDE INDEX.
3. ISCCP LONGITUDE INDEX.
4. LATITUDE OF CELL CENTER.
5. LONGITUDE OF CELL CENTER.
6. ISCCP SURFACE TYPE CODE (ISCCP PARAMETER 11).

CODE	SURFACE TYPE
1	WATER
2	LAND
3	COASTAL

7. ISCCP PRINCIPAL SATELLITE CODE (ISCCP PARAMETER 12).

CODE	SATELLITE
11	NOAA-7
61	NOAA-8
12	NOAA-9
62	NOAA-10
13	NOAA-11
63	NOAA-12
31	GOES-5
21	GOES-6
32	GOES-7
41	METEOSAT-2
42	METEOSAT-3
43	METEOSAT-4
44	METEOSAT-5
51	GMS-1
52	GMS-2
53	GMS-3
54	GMS-4

8. NUMBER OF GROUND TRUTH SITES IN CELL.
9. NUMBER OF DAYS OF MISSING ISCCP RADIANCE DATA THAT WERE FILLED, days (Staylor value). This number allows the user to know how much radiation data for this cell is based on real ISCCP data and how much is based on fill values obtained by interpolation. The Pinker algorithm also fills over gaps of missing data.
10. STAYLOR SNOW/ICE COVER, percent of month. This is the percentage of time when snow/ice cover is greater than 10 percent and the surface temperature (ISCCP PARAMETER 115) is less than 285 DEG K over a 5-day period. The value is calculated as a percentage of days when actual data are available. Thus, data gaps are assumed

to have the same snow/ice frequency as data days. When average surface temperature is greater than 285 DEG K over a 5-day period, Staylor assumes that the snow/ice cover has melted and modifies ISCCP PARAMETER 13 accordingly.

11. NUMBER OF ISCCP ALL-SKY PIXELS (linear average of daylight values of ISCCP PARAMETER 5 over the month).
12. NUMBER OF ISCCP CLOUDY-SKY PIXELS (linear average of daylight values of ISCCP PARAMETER 6 over the month).
13. ISCCP DAYLIGHT CLOUD FRACTION, dimensionless. (SRB ITEM 12/SRB ITEM 11).
14. ISCCP CLOUDY-PIXEL CLOUD OPTICAL DEPTH, dimensionless (linear average of daylight values of ISCCP PARAMETER 85 over the month).
15. ISCCP SURFACE PRESSURE, MB (linear average of daylight values for ISCCP PARAMETER 114 over the month).
16. ISCCP SURFACE TEMPERATURE (TOVS sounder product), deg K (linear average of daylight values for ISCCP PARAMETER 115 over the month).
17. ISCCP SURFACE TEMPERATURE (ISCCP clear-sky composite product), deg K (linear average of daylight values for ISCCP PARAMETER 89 over the month).
18. ISCCP TOTAL COLUMN PRECIPITABLE WATER, CM (linear average of the daylight sum of ISCCP PARAMETERS 127, 128, 129, 130, and 131 (from TOVS) over the month).
19. ISCCP TOTAL COLUMN OZONE, Dobson units (linear average of daylight values of ISCCP PARAMETER 132 (from TOVS) over the month).
20. ISCCP CLEAR-SKY COMPOSITE TOP-OF-ATMOSPHERE REFLECTANCE, dimensionless (linear average of daylight values of ISCCP CLEAR-SKY COMPOSITE SCALED RADIANCE divided by solar zenith angle [ISCCP PARAMETER 110/ISCCP PARAMETER 14], See Rossow et. al, 1987, p. 16 for discussion).
21. ERBE ALL-SKY, TOP-OF-ATMOSPHERE SW NET IRRADIANCE, W/m**2.
22. ERBE CLEAR-SKY, TOP-OF-ATMOSPHERE SW NET IRRADIANCE, W/m**2.

Downward SW surface irradiance:

23. PINKER ALL-SKY DOWNWARD SW SURFACE IRRADIANCE, W/m**2 (average of 24-hr values over the month).
24. STAYLOR ALL-SKY DOWNWARD SW SURFACE IRRADIANCE, W/m**2 (average of 24-hr values over the month).
25. GEBA SUBSET ALL-SKY DOWNWARD SW IRRADIANCE GROUND TRUTH, W/m**2.

Other parameters used to estimate downward SW surface irradiance:

26. PINKER SURFACE PRESSURE, mb (assumed value).
27. STAYLOR SURFACE PRESSURE, mb (assumed value).
28. PINKER TOP-OF-ATMOSPHERE DOWNWARD SW IRRADIANCE, W/m**2 (average of 24-hr values over the month).
29. STAYLOR TOP-OF-ATMOSPHERE DOWNWARD SW IRRADIANCE, W/m**2 (average of 24-hr values over the month).

Calculated parameters (without validation):

30. PINKER SURFACE DOWNWARD SW DIRECT/DIFFUSE RATIO (linear average of daylight values over the month).
31. PINKER CLEAR-SKY DOWNWARD SW SURFACE IRRADIANCE, W/m**2 (average of 24-hr values over the month).
32. STAYLOR CLEAR-SKY DOWNWARD SW SURFACE IRRADIANCE, W/m**2 (average of 24-hr values over the month).
33. PINKER DOWNWARD SW SURFACE "CLOUD FORCING" IRRADIANCE, W/m**2 (SRB ITEM 23-SRB ITEM 31).
34. STAYLOR DOWNWARD SW SURFACE "CLOUD FORCING" IRRADIANCE, W/m**2 (SRB ITEM 24-SRB ITEM 32).
35. PINKER SW SURFACE ALBEDO, dimensionless (SURFACE UPWARD/SURFACE DOWNWARD).
36. STAYLOR SW SURFACE ALBEDO, dimensionless (analysis of ERBE data for

land and literature values for ocean).
37. PINKER ALL-SKY SURFACE SW NET IRRADIANCE, W/m**2 (SURFACE DOWNWARD - SURFACE UPWARD).
38. STAYLOR ALL-SKY SURFACE SW NET IRRADIANCE, W/m**2 (DOWNWARD(1-SURFACE ALBEDO)).
39. PINKER ALL-SKY, TOP-OF-ATMOSPHERE SW NET IRRADIANCE, W/m**2.
40. PINKER CLEAR-SKY, TOP-OF-ATMOSPHERE SW NET IRRADIANCE, W/m**2.
41. PINKER ATMOSPHERE SW ABSORBED IRRADIANCE, W/m**2 (SRB ITEM 39-SRB ITEM 37).

Diagnostic parameters:
42. PINKER MINUS STAYLOR ALL-SKY DOWNWARD SW SURFACE IRRADIANCE, W/m**2 (SRB ITEM 23-SRB ITEM 24).
43. GEBA SUBSET GROUND TRUTH MINUS PINKER ALL-SKY DOWNWARD SW SURFACE IRRADIANCE, W/m**2 (SRB ITEM 25-SRB ITEM 23).
44. GEBA SUBSET GROUND TRUTH MINUS STAYLOR ALL-SKY DOWNWARD SW SURFACE IRRADIANCE, W/m**2 (SRB ITEM 25-SRB ITEM 24).
45. PINKER MINUS STAYLOR CLEAR-SKY DOWNWARD SW SURFACE IRRADIANCE, W/m**2 (SRB ITEM 31-SRB ITEM 32).
46. PINKER MINUS STAYLOR SURFACE SW CLOUD FORCING IRRADIANCE, W/m**2 (SRB ITEM 33-SRB ITEM 34).
47. PINKER MINUS STAYLOR SW SURFACE ALBEDO, dimensionless (SRB ITEM 35-SRB ITEM 36).
48. PINKER MINUS STAYLOR ALL-SKY SURFACE SW NET IRRADIANCE, W/m**2 (SRB ITEM 37-SRB ITEM 38).
49. PINKER MINUS ERBE ALL-SKY, TOP-OF-ATMOSPHERE SW NET IRRADIANCE, W/m**2 (SRB ITEM 39-SRB ITEM 21).
50. PINKER MINUS ERBE CLEAR-SKY, TOP-OF-ATMOSPHERE SW NET IRRADIANCE, W/m**2 (SRB ITEM 40-SRB ITEM 22).
51. DATA DATE, MMYY.
52. PROCESSING DATE, DDMMYY.

NOTE: A value of -1000 means that no data are available.

7.2 DEFINITIONS OF 10 ITEMS IN DAILY BINARY FILE srb_dayavgs_yymm

1. CELL NUMBER (1-6596, beginning at Greenwich South Pole circling east).
2. DAYLIGHT CLOUD FRACTION, dimensionless (linear average of daylight values of ISCCP PARAMETER 6/linear average of daylight values of ISCCP PARAMETER 5).
3. PINKER ALL-SKY DOWNWARD SW SURFACE IRRADIANCE, W/m**2.
4. STAYLOR ALL-SKY DOWNWARD SW SURFACE IRRADIANCE, W/m**2.
5. PINKER CLEAR-SKY DOWNWARD SW SURFACE IRRADIANCE, W/m**2.
6. STAYLOR CLEAR-SKY DOWNWARD SW SURFACE IRRADIANCE, W/m**2.
7. PINKER ALL-SKY, TOP-OF-ATMOSPHERE SW NET IRRADIANCE, W/m**2.
8. PINKER TOP-OF-ATMOSPHERE DOWNWARD SW IRRADIANCE, W/m**2.
9. DATA DATE, MMYY.
10. PROCESSING DATE, DDMMYY.

NOTE: A value of -1000 means that no data are available.

7.3 DESCRIPTION OF BINARY HIERARCHICAL DATA FORMAT (HDF) FILES

Files srb_monavgs_yymm and srb_dayavgs_yymm are stored in Version 3.2r1 HDF format. It is recommended that the user install HDF software on his or her computer system. The software is available on the National Center for Supercomputing Applications (NCSA) anonymous FTP server (ftp.ncsa.uiuc.edu, IP address 141.142.20.50) in the directory HDF/HDF3.2r1. The user may view the data by using a generic HDF read program provided by the Langley DAAC, or by importing the HDF data files into a visual data analysis transform program such as Spyglass Transform.

The SRB HDF files srb_monavgs_yymm and srb_dayavgs_yymm differ from the usual HDF convention in two ways. First, the COORDSYS parameter in the HDF subroutine DSGDAST contains the value for missing data (-1000.0000) instead of information pertaining to the coordinate system. Second, maximum and minimum values retrieved using the HDF subroutine DSGRANG are not the maximum and minimum values for a particular data month. They are, instead, a wider range used for plotting purposes.

APPENDIX A. - DESCRIPTION OF PINKER METHOD

The algorithm was developed at the University of Maryland by R. T. Pinker and I. Laszlo. It is a physical model based on radiative transfer calculations using the delta-Eddington approximation. The model is an improvement and extension on earlier concepts (Pinker and Ewing, 1985) and is described in more detail in Pinker and Laszlo (1992).

1. SHORTWAVE RADIATION BUDGET RETRIEVAL

The radiative fluxes at the boundaries of the atmosphere are computed by determining the atmospheric transmission and reflection and the surface albedo pertaining to a particular satellite observation. The upward and downward fluxes, F, at the TOA and the surface (SRF), in each of five spectral intervals spanning the range of 0.2-4.0 micrometers, are computed from the following equations:

```
F(toa,down) = PI*F0*cos(THETA0)                                   (A1)

F(toa,up) = F(toa,down)*(R0(THETA0)+r*TTILDA)                     (A2)

F(srf,down) = F(srf,down,dir)+F(srf,down,dif)                     (A3)

            = F(toa,down)*(T0(dir,THETA0)
                  +T0(dif,THETA0)+r*RTILDA)

F(srf,up) = a(dir)*F(srf,down,dir)+a(dif)*F(srf,down,dif)         (A4)
```

where:

```
r = (a(dir,THETA0)*T0(dir,THETA0)+a(dif,THETA0)*T0(dif,THETA0))/
      (1-a(dif,THETA0)*RTILDA)                                    (A5)
```

In the equations above, THETA0 is the solar zenith angle, PI*F0 is the extraterrestrial irradiance, and R0(THETA0) and T0(THETA0) are the reflectivity and transmissivity of the atmosphere over a nonreflecting surface, respectively. The terms dir and dif refer to the direct and diffuse components of (1) the surface downward flux (F(srf,down,dir) and F(srf,down,dif)), (2) the transmissivity (T0(dir,THETA0) and T0(dif,THETA0)), and (3) the surface albedo (a(dir) and a(dif)). RTILDA and TTILDA are the spherical reflectivity and transmissivity, respectively, representing the integrals of R0(THETA0) and T0(THETA0) over THETA0. The reflectivities R0(THETA0), RTILDA and transmissivities T0(dir,THETA0), T0(dif,THETA0), TTILDA (hereafter optical functions) are functions of the composition of the atmosphere: amount of water vapor, ozone, aerosol, and cloud.

To compute the fluxes from equations (A1) through (A4), the spectral surface albedos a(dir) and a(dif) and the optical functions should be determined. The algorithm retrieves them from the satellite-measured value of the TOA narrowband visible radiance and from satellite-retrieved values of ozone and water vapor abundances by comparing the satellite radiances to a radiative model. The radiative model contains spectral values of the optical functions precomputed for discrete values of the solar zenith angle as well as amounts of water vapor, ozone, aerosol, and cloud optical depth. It is currently based on the delta-Eddington approximation of the radiative transfer in a vertically inhomogeneous, scattering, and absorbing atmosphere (see section 2 of this appendix). The delta-Eddington approximation was chosen over more sophisticated methods because it provides fast and relatively accurate computations of fluxes over a wide range of optical parameters.

The imaging instruments on board the operational satellites measure radiances in narrow spectral bands. To retrieve optical functions, the measured narrowband radiances should be compared with modeled quantities of the same type. The delta-Eddington approximation, however, provides fluxes, not radiances. Moreover, the narrowband satellite radiances cannot be simulated because the five spectral intervals of the radiative model are too course for incorporating the filter functions of the various imaging instruments. Therefore, the broadband (0.2-4.0 micrometer) TOA albedos are used for the comparison between satellite-derived and modeled quantities. For this purpose, the satellite-measured narrowband radiances are first transformed into broadband reflectances by applying narrow-to-broadband conversions (Laszlo et al., 1988) for clear ocean, land, desert, snow, and cloudy scenes:

R(b,THETA,THETA0,PHI) = M*R(THETA,THETA0,PHI,n)+B   (A6)

where:

R(n,THETA,THETA0,PHI) = (PI*L(THETA,THETA0,PHI))
/(PI*F0*cos(THETA0))   (A7)

Here THETA and PHI are the satellite zenith angle and the relative azimuth angle, respectively. R(n,THETA,THETA0,PHI) is the narrowband bidirectional reflectance computed from the satellite-measured radiance L(THETA,THETA0,PHI), and R(b,THETA, THETA0, PHI) is the broadband reflectance. M and b are the slope and offset of the narrow-to-broadband conversion, respectively. The broadband reflectance is then converted into a broadband albedo (R(b,THETA0)) using the anisotropic factors (CHI(THETA,THETA0,PHI)) of Suttles et al. (1988) given as:

R(b,THETA0) = R(b,THETA,THETA0,PHI)/CHI(THETA,THETA0,PHI)   (A8)

The spectral surface albedo is determined in two steps. First, by applying the transformations mentioned above, a broadband TOA upward flux is obtained from the narrowband clear-sky composite radiance in the ISCCP data. This radiance is a "time average" of the clear-sky radiances, and it is assumed that it represents typical (climatological) surface and aerosol conditions. Next, a broadband TOA upward flux is calculated by summing up the spectral fluxes obtained from (A2). The optical functions used in (A2) are determined for satellite-retrieved values of ozone and water vapor amounts and climatological values of aerosol optical depths. The spectral surface albedos are prescribed from the ocean and land albedo models of Briegleb et al. (1986) and the snow albedo model of Wiscombe and Warren (1980) (see section 2.5 of this appendix). The calculated flux is then compared to the one obtained from the narrowband clear-sky composite radiance. If there is no agreement, the spectral values of the surface albedo models are adjusted (multiplied by a constant), and the second step is repeated until a match of the TOA fluxes is achieved. The adjusted surface albedos that yield a match of the TOA fluxes constitute the retrieved values of the surface albedo.

The procedures described above require satellite and scene identification. The ISCCP data provide most of the needed information: type of satellite used and clear/cloudy scene identification. Discrimination between clear scenes (ocean, land, and desert) is based on the work of Matthews (1985).

Once the surface albedo is known, the optical functions for clear and cloudy conditions are determined by matching the broadband TOA albedos, derived from the clear and cloudy radiances of the ISCCP data, respectively, with TOA albedos in the radiative model of the surface-atmosphere system. Since the amounts of ozone, water vapor, and the surface albedo are given, the process requires searching through various values of the aerosol optical thickness for clear-sky conditions and of the cloud optical thickness for cloudy-sky conditions until a match in the TOA albedos is found. The optical functions associated with the model which provide the best match are taken as the retrieved values. The retrieved optical functions, along with the surface albedos, are then used in equations (A1) through (A4) to compute the fluxes for clear (F(clear)) and cloudy (F(cloudy)) conditions. The all-sky flux, F(all), is obtained by using the information on cloud cover:

$$F(all) = ((n(clear)*F(clear))+(n(cloudy)*F(cloudy)))/(n(clear)+n(cloudy)) \quad (A9)$$

where n(clear) and n(cloudy) are the number of clear and cloudy pixels from which the clear and cloudy ISCCP radiances are obtained.

The instantaneous fluxes computed from (A9) are integrated numerically for the daylight hours and divided by 24 hours to obtain a daily average. At times when no observations are available, the fluxes are interpolated from the preceding and following observations. Because of the finite number of observations available per day, the total daily flux obtained from numerically integrating the instantaneous fluxes is potentially inaccurate. Therefore, the daily total fluxes are adjusted by the ratio of the TOA incoming flux as obtained by an analytical integration to that computed from the numerical integration. To account for missing days in the monthly averages, first, an average TOA and surface albedo and an average transmittance are computed from the daily average fluxes. The monthly mean TOA downward flux computed analytically (FBAR(toa,down,analytical)) is then multiplied by the average TOA albedo to yield the monthly mean of the TOA upward flux. Similarly, the product of FBAR(toa,down,analytical) and the average transmittance gives the monthly mean of the surface downward flux. The monthly mean of the surface upward flux is then obtained by multiplying monthly mean surface downward flux by the average surface albedo. The above procedure assumes that the days with observations are representative of the entire month.

The parameters of the ISCCP data used as inputs to the algorithm, and their primary functions, are summarized in Table A1.

TABLE A1. - INPUT PARAMETERS AND THEIR PRIMARY FUNCTIONS

INPUT PARAMETER	FUNCTION
Clear-Sky Radiance	To get fluxes for clear-sky conditions
Cloudy-Sky Radiance	To get fluxes for cloudy-sky conditions
Clear-Sky Composite Radiance	To get surface albedo
Number of Clear Pixels	To weight clear-sky fluxes for all-sky conditions
Number of Cloudy Pixels	To weight cloudy-sky fluxes for all-sky conditions
Water Vapor and Ozone Amount	To select optical functions
Solar and Satellite Zenith and Relative Azimuth Angles	To select anisotropic correction factors
Latitude and Longitude	To select clear-scene type and surface albedo model
Satellite ID	To select appropriate narrow-to-broadband transformation
Snow Cover	To weight snow albedo

2. ATMOSPHERIC RADIATIVE TRANSFER COMPONENT

The reflected and transmitted radiation are computed for a plane-parallel, vertically inhomogeneous, scattering and absorbing atmosphere in five spectral intervals (0.2-0.4, 0.4-0.5, 0.5-0.6, 0.6-0.7, 0.7-4.0 micrometer) using the delta-Eddington approximation of radiative transfer. The rationale for the selection of the delta-Eddington approach and the accuracy of this method are discussed in Pinker and Ewing (1985). The atmospheric radiative transfer model accounts for (1) absorption by ozone and water vapor; (2) multiple scattering by molecules; (3) multiple scattering and absorption by aerosols and cloud droplets; and (4) multiple reflection between the atmosphere and the surface. It has five or six layers, depending on the aerosol profile considered and on whether a cloud is present. The parameterizations used in the atmospheric radiative transfer model will be described in the following section.

2.1 OZONE AND WATER VAPOR ABSORPTION

The fraction of the incident solar radiation absorbed by ozone in a layer, A, is computed following Lacis and Hansen (1974):

```
A = A(x) + R(THETA0)*A(x)                                    (A10)
```

where THETA0 is the solar zenith angle, R(THETA0) is the reflectivity of the atmosphere-surface system below the absorbing ozone layer, and x is the relative optical ozone pathlength. The first term represents the absorption of the downwelling direct radiation, while the second one gives the absorption of the upwelling diffuse radiation. Ozone absorption is accounted for in the 0.2-0.4 micrometer (UV) and in the 0.5-0.6 micrometer (VIS) spectral intervals (Lacis and Hansen, 1974):

```
AUV = (1.082*x)/((1+(138.6*x))**0.805)
             +(0.0658*x)/(1+((103.6*x)**3))                  (A11)

AVIS = (0.02118*x)/(1+(0.042*x)+(0.000323*(x**2)))           (A12)
```

The absorption by water vapor, Awv, in the 0.7-4.0 micrometer band is computed in terms of the discrete probability distribution (p(kn)) of the absorption coefficients (kn) following Lacis and Hansen (1974):

```
Awv(Y(L)) = 1-summation from n=1 to n=8
                   of (p(kn)*e**(-kn*Y(L)))                  (A13)
```

Here Y(L) is the effective water vapor amount (temperature and pressure scaled amount) in the Lth atmospheric layer. The amount of ozone and the effective water vapor amount in each layer of the atmosphere were obtained from detailed data on ozone and water vapor densities, temperature, and pressure at 31 levels of the Standard Atmospheres (tropical, mid-latitude summer and winter, subarctic summer and winter) (Kneizys et al., 1980).

2.2 RAYLEIGH SCATTERING

The Rayleigh scattering optical depth of a layer, dTAU, between levels L and L-1 (Penndorf, 1957) is expressed as:

```
DTAU = 27.019*t*((1+(0.5*(z(L-1)+z(L)))/6371)**2)*(1+29/18r)
                                /(1+r)(p(L)-p(L-1))  (A14)
```

where:

- z(L), z(L-1) - heights (km) at levels L and L-1
- p(L), p(L-1) - pressures (mb) at levels L and L-1
- r - relative humidity in the layer
- t - a function of wavelength, depolarization factor, and the refractive index of the air.

Equation (A14) includes corrections for humidity and the variation of gravitation with altitude. The parameter t was computed with the high spectral resolution radiation model ATRAD (Wiscombe et al., 1984). The spectral values of parameter t are listed in table A2.

TABLE A2. - THE SPECTRAL VALUES OF PARAMETER

SPECTRAL INTERVAL (micrometers)	0.2-0.4	0.4-0.5	0.5-0.6	0.6-0.7	0.7-4.0
t	2.7E-5	8.2E-6	3.6E-6	1.8E-6	3.6E-7

2.3 AEROSOL EXTINCTION

Two atmospheric aerosol profiles (MAR-I and CONT-I) of the Standard Radiation Atmosphere (WCP-55, 1983) are used in the radiative transfer computations. They depict typical maritime and average rural-continental conditions, respectively. These profiles specify the optical properties of the atmosphere in five layers in terms of optical depth, single scattering albedo, and asymmetry parameter. In each layer, the chemo-physical characteristic of the aerosol is given by one of the basic aerosol types: continental, maritime, background stratospheric, and upper atmospheric.

2.4 CLOUD EXTINCTION

The cloud parameterization of Stephens et al. (1984) for two broad spectral intervals in the shortwave region (0.2-0.75 micrometer and 0.75-4.0 micrometer) was adopted. It is expressed in terms of optical thickness, TAU, single scattering albedo, OMEGA, and backscattered fraction of monodirectional incident radiation BETA(MU0), as a function of the cosine of the solar zenith angle, MU0. In the solar model the radiative transfer is treated in the framework of the delta-Eddington approximation; the optical properties are described by TAU, OMEGA, and the asymmetry parameter, g. In order to implement the cloud parameterization of Stephens into the delta-Eddington scheme, it is necessary to relate BETA(MU0) to g.

The single scattering albedos and the asymmetry parameters used in the delta-Eddington approximation (see Table 2 of Pinker and Laszlo (1992)) have been derived iteratively so that they yield the same reflectance and absorption of clouds as those obtained from the Stephens' parameterization scheme. This method allows the inclusion of aerosols in the atmospheric column. The parameterization of Stephens does not account for aerosol extinction. Because it was assumed by Stephens that the cloud does not absorb in the visible spectrum, the ability to include aerosol extinction is important. In all the radiative transfer computations, the spectral interval was (0.2-4.0 micrometer) to be compatible with the parameterization of Stephens. To keep the computations at a manageable level, a single plane-parallel cloud layer is assumed and both the geometrical thickness and cloud top height are fixed.

2.5 SURFACE REFLECTIVITY

The ocean- and land-albedo models of Briegleb et al. (1986) were adopted to prescribe the surface reflectance as a function of solar zenith angle, THETA0, and wavelength, LAMBDA. In the land-albedo models each surface is considered to consist of two components, a(1,THETA0,LAMBDA) and a(2,THETA0,LAMBDA), with fractions f and (1-f):

$$a(\mathrm{THETA0},\mathrm{LAMBDA}) = f*a(1,\mathrm{THETA0},\mathrm{LAMBDA}) + (1-f)*a(2,\mathrm{THETA0},\mathrm{LAMBDA}) \qquad \text{(A15)}$$

The albedo of each component k (k = 1,2) is given as a function of the solar zenith angle, the albedo for THETA0 = 60 degrees and an empirical parameter, d(k) (Dickinson, 1983):

```
a(k,THETA0,LAMBDA) = a(k,60 degrees,LAMBDA)
                     *(1+d(k))/(1+2*d(k)*cos(THETA0)).        (A16)
```

In the surface albedo models a0 is specified for four spectral intervals in the shortwave band with boundaries at 0.2, 0.5, 0.7, 0.85 and 4.0 micrometers, as well as the values of dk and the fractions, f, for each component. The above parameters and the surface reflectivities based on surface and aircraft measurements are specified for 10 surface types (Briegleb et al., 1986). It is assumed that land surface albedos are the same for both the direct and the diffuse components of the solar irradiance.

The ocean-albedo for direct solar radiation is obtained from the following expression (Briegleb et al., 1986):

```
a(dir,THETA0) = (2.6/((((cos(THETA0))**1.7)+0.065))
 +(15(cos(THETA0)-0.1)*(cos(THETA0)-0.5)*(cos(THETA0)-1))      (A17)
```

For diffuse irradiance, a constant albedo value, a(dif), of 6 percent is used. The spectral albedos of snow for the direct and diffuse irradiance are computed from the semi-infinite snow model of Wiscombe and Warren (1980), assuming pure, fresh snow with a grain size of 50 micrometers. When the snow cover reported in the ISCCP data is less than 100 percent, the albedo is computed as a weighted average of the land/ocean and snow albedos.

APPENDIX B. - DESCRIPTION OF STAYLOR METHOD

The algorithm was developed at NASA Langley Research Center by W. F. Staylor. It is an empirical/physical model that utilizes ISCCP-C1 data (Schiffer and Rossow, 1983) as its primary input data. The current model is a modified version of an earlier model by Darnell et al. (1988), hereafter D88, that utilized TOVS meteorological data (Smith et al., 1979) and Heat Budget Product radiance data (Gruber, 1978) as input data to estimate surface insolation. A recent application of the method is given in Darnell et al., 1992.

1. ATMOSPHERIC RADIATIVE TRANSFER COMPONENTS

The current insolation model uses a broadband shortwave approach which assumes that insolation at the surface for all-sky conditions (clear and cloudy), ISASi, can be related as the product of insolation at the top of the atmosphere, ITOAi, clear-sky atmospheric transmittance, TA, and cloud transmittance, TC,

$$\text{ISASi} = \text{ITOAi*TA*TC} \ . \qquad \text{(B1)}$$

This is an instantaneous expression (i) and it is assumed that TA and TC are independent. ITOAi is given by

$$\text{ITOAi} = \text{S*cos(theta)} \qquad \text{(B2)}$$

where S is the Earth-Sun distance-corrected solar flux and theta is the solar zenith angle.

Atmospheric transmittance can be expressed as

$$\text{TA} = \text{(1+0.065*PS*AS+2*J*AS)*exp(-TAU,theta)} \qquad \text{(B3)}$$

where PS is the surface pressure, AS is surface albedo, J is an aerosol parameter, and (TAU,theta) is the effective clear-sky atmospheric optical depth. The first term in brackets relates the atmospheric backscattering of surface reflected flux (treated as negative optical depth in D88). The 0.065 coefficient is the average of values given by Lacis and Hansen (1974) and Hoyt (1978). Surface albedo will be treated later (see SURFACE ALBEDO). In Fig. 2 of D88, it was found that (TAU,theta) and the optical depth at zero degrees solar zenith angle, (TAU,zero) were related as

$$\text{TAU,theta} = \text{TAU,zero*(sec(theta))**N} \qquad \text{(B4)}$$

and the power, N, could be calculated as

$$\text{N} = \text{2.1*(log(TAU,70.5 deg)-log(TAU,0 deg))} \ . \qquad \text{(B5)}$$

Vertical optical depth (theta = 0 degrees) is defined as

$$\text{TAU,zero} = \text{-ln(1-(ALPHA,zero))} \qquad \text{(B6)}$$

where (ALPHA,zero) is the effective downward attenuation factor for solar energy due to all absorption and scattering processes (clear-sky only). ALPHA,zero is the summation of six components given as

$$\begin{aligned}\text{ALPHA,zero} = {} & \text{ALPHA,WV + ALPHA,OZ + ALPHA,O2} \\ & \text{+ ALPHA,CO2 +ALPHA,RAY + ALPHA,AER} \ . \qquad \text{(B7)}\end{aligned}$$

Lacis and Hansen (1974) gave equations for the broadband absorptions of water vapor and ozone which are approximated here as

$$ALPHA,WV = 0.100*(WV)**0.27 \tag{B8}$$

and

$$ALPHA,OZ = 0.037*(OZ)**0.43 . \tag{B9}$$

Yamamoto (1962) gave equations for the broadband absorptions of oxygen and carbon dioxide which are approximated here as

$$ALPHA,O2 = 0.002*(PS)**0.87 \tag{B10}$$

and

$$ALPHA,CO2 = 0.006*(PS)**0.29 . \tag{B11}$$

Rayleigh attenuation was estimated by Lacis and Hansen (1974) as

$$ALPHA,RAY = 0.035*PS**0.67 . \tag{B12}$$

Aerosol attenuation was based on World Climate Program models (World Climate Research Program, 1983) given here as

$$ALPHA,AER = J/2 + K . \tag{B13}$$

The J term is equal to aerosol optical depth times the quantity 1 minus the asymmetry factor, and K is equal to the optical depth times the quantity 1 minus the single-scattering albedo. Values for J and K are given in Table B1 for five surface types.

It should be noted that the Rayleigh and aerosol attenuation terms are concerned only with backscattering and/or absorption, but not with forward scattering of flux which reaches the surface.

With values of S, PS, AS, WV, OZ, J, K, and TC (see INPUT DATA), one could compute the instantaneous insolation at the surface as a function of theta using equations (B1) through (B13). Computation of the daily insolation (d) involves the time integration of the instantaneous insolation (i) from sunrise (sr) to sunset (ss) which can be approximated as:

```
ISASd = S*TC*(1 + 0.065*PS*AS+2*J*AS)
    *integral(exp(-TAU,theta)*cos(theta)*dt) taken from sr to ss   (B14)
```

where PS, AS, S, J, and TC are assumed to be constant for a region during the course of each day. Equation (14) can be evaluated as

```
ISASd = S*H*TC*(1 + 0.065*PS*AS+2*J*AS)*exp(-TAU,zero*(UE)**-N)    (B15)
```

where H is the daily vertical Sun fraction and UE is the effective daily cosine of the solar zenith angle. Both H and UE are defined in Table B2. Cloud transmittance is based on a threshold technique (D88, Fig. 7) given by

$$TC = 0.05 +0.95*(Ro-Rm)/(Ro-Rc) \tag{B16}$$

where Ro, Rc, and Rm are the TOA reflectances for overcast, clear-sky and measured conditions, respectively. The coefficients 0.05 and 0.95 (rather than 0 and 1) simply relate the observation that for totally overcast days (Rm=Ro), cloud transmittance is about 5 percent, not zero. Each of the three reflectance terms in equation (B16) is a daily value obtained by weighting the ISCCP 3-hourly instantaneous values with the cosine of the solar zenith angle, UO. The measured value, for instance, would be

$$Rm = summation\ Rmi*UO/summation\ UO . \tag{B17}$$

Instantaneous overcast reflectances are estimated from a model by

Staylor (1985) as

$$Roi = D1/(UO*UV) + (D2/(UO*UV))*((UO*UV)/(UO + UV))**2 \quad (B18)$$

where UV is the cosine of the viewing zenith angle and D1 and D2 are ISCCP satellite coefficients given in Table B3. These coefficients are determined using ISCCP data for non-snow, totally overcast regions with mean cloud optical depths greater than 80 for each satellite for every month. A linear regression of (Roi*UO*UV) versus ((UO*UV)/(UO + UV))**2 is performed to determine D1 and D2.

Clear-sky reflectances are determined by one of several methods depending on the surface type and snow cover. For ocean regions, which cover the majority of the Earth's surface,

$$Rci = D3 + D4*((UO*UV)**-0.75) \quad (B19)$$

where D3 and D4 are ISCCP satellite coefficients, given in Table B3, that were determined for totally clear ocean regions for each satellite every month. A linear regression of (Rci) versus ((UO*UV)**-0.75) is performed to determine D3 and D4. For land regions where there is no snow or where the snow cover does not change by more than 10 percent during the month, daily Rc values are computed from the clear-sky pixels and the minimum value for the month is used for the entire month. If the snow cover changes by more than 10 percent during the month (determined for 5-day intervals), the above procedure is still used, but is applied to several shorter time intervals.

Measured instantaneous reflectances, Rmi, are the pixel-weighted average of the clear and cloudy pixel reflectances which are then UO-weighted to produce the daily Rm values (equation B17). If only a single Rmi value exists for a day (average of about 4 for the ISCCP geostationary satellites), a value of Rm can be computed for that day. But if no Rmi value exists for a day (occurs most frequently in regions of polar satellite coverage), a fill value is provided by one of two methods. If an Rm value exists for an adjacent longitudinal region for that day, it is used. If it does not exist, then the previous day's value of Rm is used. This procedure is expanded spatially, then temporally until a non-fill value of Rm is found.

2. SURFACE ALBEDO

A daily surface albedo value for all-sky conditions, AS, is needed for the computation of insolation (equation B15), and it is also used in the computation of surface absorbed insolation which is given by

$$IAASd = ISASd*(1-AS) \ . \quad (B20)$$

The all-sky albedo is estimated as

$$AS = Aso + (Asc - Aso)*(TC)**2 \quad (B21)$$

where Aso is the daily overcast albedo and Asc is the daily clear-sky albedo. Because of the difficulty of obtaining consistent surface albedos using the visible (0.5 - 0.7 micron: GOES, GMS, NOAA) and near-infrared (0.7 - 1.1 micron; METEOSAT) radiances from ISCCP, daily clear-sky albedo results from Staylor and Wilber (1990) were used which were based on broadband ERBE scanner data. Daily overcast albedos are estimated to be equal to the instantaneous clear-sky albedos for a solar zenith angle of 53 degrees (cosine = 0.6) as that is approximately the effective downward zenith angle of diffuse rays from clouds. For oceans,

$$Aso = 0.065 \ , \quad (B22a)$$

and for land

$$Aso = 1.1*Asc*(UE)**0.2 . \tag{B22b}$$

3. INPUT DATA

ISCCP data sets contain data bytes (b) for 132 parameters which are given once every 3 hours (0, 3, 6, 9, 12, 15, 18, 21 GMT). Surface pressure is given in millibars (1000 mb = sea level pressure) and is converted to atmospheres as

$$PS = b114/1000 . \tag{B23}$$

Precipitable water vapor is given in centimeters for each of five layers and converted to total burden in precipitable centimeters as

$$WV = b127 + b128 + b129 + b130 + b131 . \tag{B24}$$

Ozone is given in Dobson units and converted to atmosphere-cm as

$$OZ = b132/1000 . \tag{B25}$$

The cosine of the solar zenith angle, UO, is b14/100 and the cosine of the viewing zenith angle, UV, is b15/100. Snow coverage in percent is b13. Total number of pixels in a region is b5, and the number of those which are cloudy is b6. Mean scaled reflectance (Rmi*UO) for the cloudy pixels is b104, and mean scaled reflectance for the clear pixels is b107.

Solar declinations and Earth-Sun distances were calculated each day using an algorithm. A solar flux of 1365 W/m**2 was used for an Earth-Sun distance of 1AU. As mentioned previously, surface albedos were derived from ERBE scanner data (Staylor and Wilber, 1990).

TABLE B1. - AEROSOL MODELS

SURFACE	J	K
OCEAN	0.06*UE	0.008*UE
LAND	0.12*UE	0.035*UE
COASTAL	0.09*UE	0.020*UE
DESERT	0.20*UE	0.040*UE
ICE/SNOW	0.010	0.001

TABLE B2. - DEFINITION OF INSOLATION PARAMETERS

	FF/GG > 1 no sunset	1 >FF/GG > - 1 sunrise and sunset	FF/GG < -1 no sunrise
H =	FF	(1/PI)*(FF*arccos(-FF/GG)+GG*(1-(FF/GG)**2)**0.5)	0
UE=	FF	FF + GG*((GG-FF/2*GG)**0.5)	-

FF = sin(ELAT)*sin(SDEC)

GG = cos(ELAT)*cos(SDEC)

ELAT = Effective latitude of a region, area-centered

SDEC = Solar declination

TABLE B3. - ISCCP SATELLITE COEFFICIENTS
(Values applicable from April 1985 to January 1986)

Satellite	CODE	D1	D2	D3	D4
NOAA 9	12	0.023	3.08	-0.007	0.040
GOES 6 (WEST)	21	0.000	3.40	0.002	0.038
METEOSAT 2	41	0.004	3.35	-0.010	0.040
GMS 3	53	0.005	3.38	-0.012	0.040

Note: The coefficients used in Table B3 represent an average over several months of data in an attempt to minimize uncertainties.

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Shortwave radiative fluxes which reach the Earth's surface are key elements that influence both atmospheric and oceanic circulation. The World Climate Research Program has established the Surface Radiation Budget climatology project with the ultimate goal of determining the various components of the surface radiation budget from satellite data on a global scale. This report describes the first global product that is being produced and archived as part of that effort. The interested user can obtain the monthly global data sets free of charge using email procedures.

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